
NESA Student number

2023
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- Use the separate multiple-choice answer sheet provided
- Write your Student Number in the space provided at the top of pages 1, 12 & on the multiple-choice answer sheet

SECTION	TOTAL	MARKS
I	20	
II	80	
TOTAL	100	

Total marks – 100

Section I Pages 3-11

20 marks
- Attempt Questions 1-20
- Allow about 35 minutes for this part

Section II Page 12-28

80 marks
- Attempt Questions 21-35
- Allow about 2 hours and 25 minutes for this part
- Extra paper if required on p. 29-30

ALL QUESTIONS ARE COMPULSORY

Disclaimer: This trial paper does not necessarily reflect the content or format of the 2023 Chemistry HSC exam.

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Section I
20 marks

Attempt Questions 1–20
Allow about 35 minutes for this part

Use the separate multiple-choice answer sheet for Questions 1–20

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1. The forward reaction in the equilibrium shown is endothermic.

$$OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$$

Which change increases the concentration of the hypochlorous acid (HOCl)?

(A) Adding water

(B) Adding sodium hypochlorite, NaOCl(s)

(C) Adding hydroxide ions

(D) Lowering the temperature

2. 0.1 moles of each of the following substances is dissolved in 1 L of water. For which substance would the pH of the solution be the closest to 14?

(A) $Ca(OH)_2$

(B) CH_3CH_2OH

(C) NH_4Cl

(D) $NaCH_3COO$

3. A saturated solution of $BaSO_4$ is maintained at constant temperature. Solid soluble Na_2SO_4 is added to this solution. What happens to the Ba^{2+} and SO_4^{2-} ion concentrations in the resultant solution compared to the initial solution?

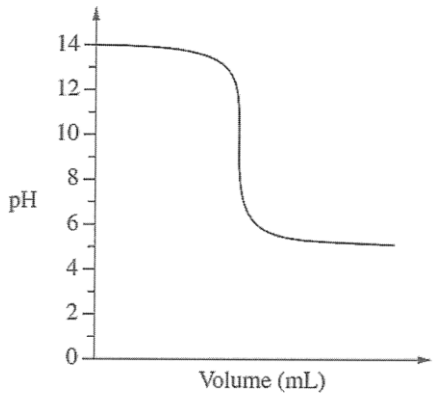
(A) Ba^{2+} concentration increases and SO_4^{2-} concentration remains the same

(B) Ba^{2+} concentration increases and SO_4^{2-} concentration increases

(C) Ba^{2+} concentration decreases and SO_4^{2-} concentration increases

(D) Ba^{2+} concentration decreases and SO_4^{2-} concentration remains the same

4. The graph shows the changes in pH during a titration



Which indicator should be chosen for this titration?

(A) Methyl orange (pH range 3.1 – 4.4)

(B) Bromocresol green (pH range 4.5 – 5.2)

(C) Bromothymol blue (pH range 6.0 – 7.6)

(D) Phenolphthalein (pH range 8.3 – 10.0)

5. Which of these substances is an example of a polyprotic acid?

(A) HCl

(B) HNO_3

(C) H_3CrO_4

(D) CH_3COOH

6. Below is an equation for a reversible reaction.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

The reaction's correct equilibrium expression is:

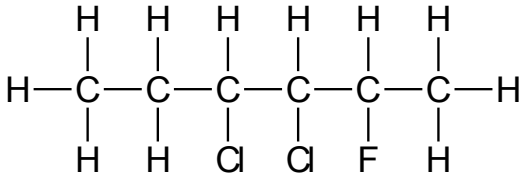
(A) $\frac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}][H^+]}$

(B) $\frac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}]^2[H^+]^2}$

(C) $\frac{[Cr_2O_7^{2-}][H_2O]}{[CrO_4^{2-}]^2[H^+]^2}$

(D) $\frac{[CrO_4^{2-}]^2[H^+]^2}{[Cr_2O_7^{2-}]}$

7. What is the IUPAC name of the following compound?



(A) 5-fluoro-3,4-dichlorohexane

(B) 2-fluoro-3,4-dichlorohexane

(C) 3,4-dichloro-5-fluorohexane

(D) 3,4-dichloro-2-fluorohexane

8. Chlorine gas (Cl_2) and carbon monoxide gas (CO) are placed in a sealed container and kept at a temperature of 25°C. Phosgene gas is produced as follows:

$$Cl_2(g) + CO\ (g) \rightleftharpoons COCl_2(g)$$

Which statements about this reaction are correct?

(A) All the Cl_2 and CO will be converted into $COCl_2$

(B) At a temperature of 25°C the $COCl_2$ will not form

(C) The forward reaction will continue to occur until the concentration of $COCl_2$ remains constant

(D) When the forward and reverse reactions become equal the concentration of $COCl_2$ becomes constant

9. The molar masses of C_2H_6, CH_3OH and CH_3F are similar. Which of the following lists these compounds in order of increasing boiling point?

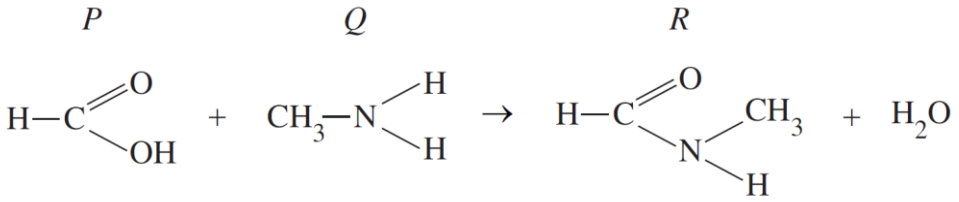
(A) $C_2H_6 < CH_3OH < CH_3F$

(B) $C_2H_6 < CH_3F < CH_3OH$

(C) $CH_3F < CH_3OH < C_2H_6$

(D) $CH_3OH < CH_3F < C_2H_6$

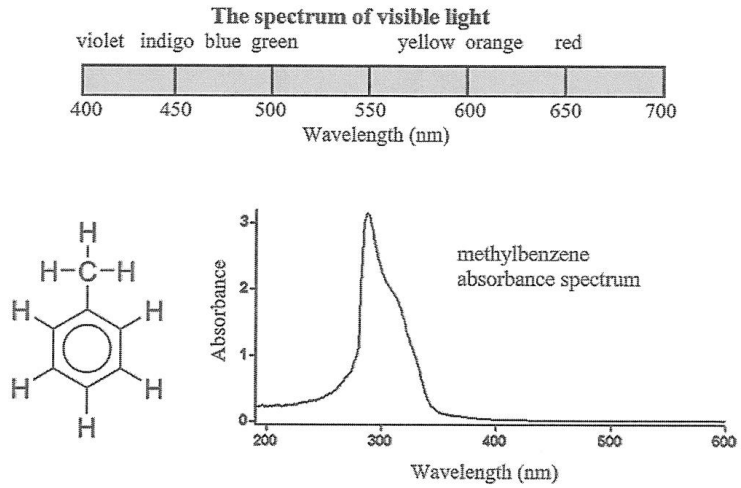
10. The diagram below shows molecules P and Q reacting to form R and water.



Which row of the table correctly identifies the molecule types?

	P	*Q*	*R*
(A)	carboxylic acid	amine	amide
(B)	carboxylic acid	amide	amine
(C)	alcohol	amine	ester
(D)	aldehyde	amide	ketone

11. The spectrum of visible light, structural formula and UV absorption spectrum of methylbenzene is shown.



Based on the information, which statement about methylbenzene is correct?

(A) A solution of methylbenzene would appear colourless

(B) A solution of methylbenzene would appear as an orange-red colour

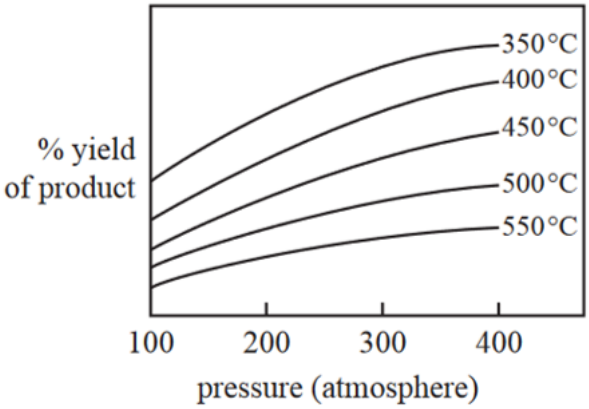
(C) Methylbenzene only absorbs in the visible part of the electromagnetic spectrum

(D) Methylbenzene does not absorb wavelengths lower than 100 nm

12. The graph below refers to the following gaseous reaction.

$$aA(g) + bB(g) \rightleftharpoons cC(g) + dD(g)$$

The effect of increasing pressure and temperature on the equilibrium yield of products is shown in the graph below.



Which of the following alternatives regarding the equilibrium systems is consistent with the data above?

	Relative numbers of moles of products and reactants	*ΔH*
(A)	a + b < c + d	-
(B)	a + b < c + d	+
(C)	a + b > c + d	-
(D)	a + b > c + d	+

13. Which of the following pairs of compounds will form a precipitate when 0.1 mol L^{-1} solutions of each are mixed?

(A) $AgNO_3$ and $Ba(NO_3)_2$

(B) K_2SO_4 and $Cu(NO_3)_2$

(C) $Ca(NO_3)_2$ and KBr

(D) NaOH and $CuCl_2$

14. A student performed a titration to determine the concentration of an unknown sodium hydroxide solution using a standard solution of hydrochloric acid. They performed the following steps:

- A burette was rinsed with deionised water, then rinsed again with the sodium hydroxide solution.
- The burette was then filled with the sodium hydroxide solution.
- A volumetric pipette and a conical flask were both washed with deionised water, then washed again with the hydrochloric acid solution.
- 25 mL of the hydrochloric acid solution was transferred into the conical flask using the pipette and an appropriate indicator added.
- Titration performed until the endpoint, and the titrant volume recorded.

The accuracy of the student's value was determined by comparing it to the true value. The calculated concentration based on the method described above will be:

(A) Higher than the true value

(B) Lower than the true value

(C) The same as the true value

(D) Different than the true value, but there is insufficient information to determine if it would be higher or lower

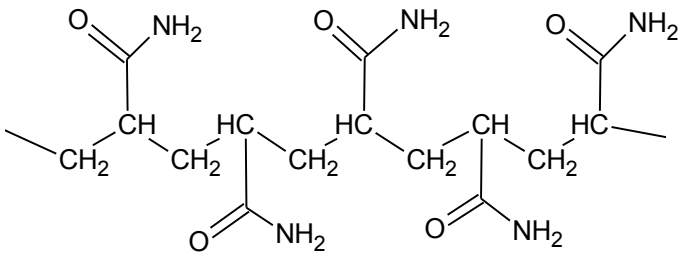
15. Four organic compounds are identified by the numbers I, II, III, IV.

I – CH_3CH_2COOH
II – CH_3CH_2OH
III – $CH_3CH2CONH_2$
IV – $CH_3CH_2NH_2$

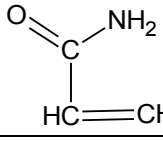
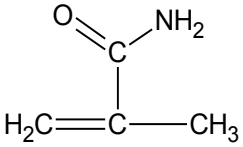
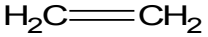
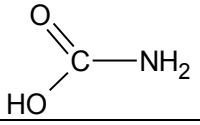
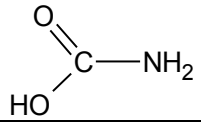
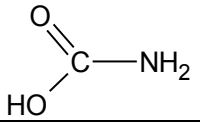
Which alternative identifies the strongest acid and strongest base in the list?

	Strongest acid	*Strongest base*
(A)	I	III
(B)	I	IV
(C)	II	III
(D)	II	IV

16. The diagram below shows a polymer.



Identify the type of polymerisation reaction used to produce it and the monomer or monomer units used to make it.

	Type of polymerisation	*Monomer 1*	*Monomer 2*
(A)	Addition		N/A
(B)	Addition		N/A
(C)	Condensation		
(D)	Condensation		

17. What is the function of the hollow cathode lamp in an atomic absorption spectrometer?

(A) Provide a specific wavelength of light that can be absorbed by free atoms in the gaseous state

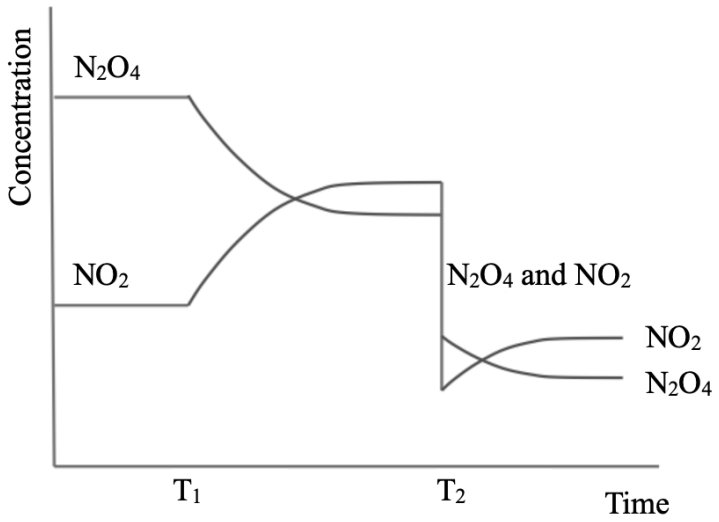
(B) Separate molecules in the tested sample so that free atoms are formed

(C) Convert free atoms in the tested sample into gaseous ions

(D) Produce a frequency of light that is absorbed by particular bonds of molecules in the sample being tested

18. The graph shows the concentrations over time for the equilibrium system:

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58 \text{ kJ.mol}^{-1}$$



What has happened to the temperature at T_1 and to the volume at T_2?

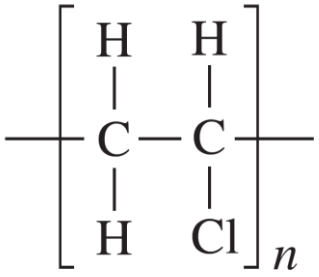
(A) Temperature ***decreased*** at T_1 and volume ***increased*** at T_2

(B) Temperature ***increased*** at T_1 and volume ***decreased*** at T_2

(C) Temperature ***decreased*** at T_1 and volume ***decreased*** at T_2

(D) Temperature ***increased*** at T_1 and volume ***increased*** at T_2

19. A researcher was examining a sample of the polymer polyvinyl chloride (PVC) to determine its chain length. The sample was found to have a molar mass of 623 800 g mol^{-1}. A section of the chain is shown.



What is the value of n?

(A) 789.8

(B) 2494

(C) 9982

(D) 155 950

20. 1.23 g of a pure acid, $H_2X(s)$, is added to exactly 250.0 mL of 0.100 M NaOH(aq).

$$H_2X(s) + 2NaOH(aq) \rightarrow Na_2X(aq) + 2H_2O(l)$$

The NaOH is in excess. This excess NaOH requires 27.50 mL of 0.20 M HCl(aq) for neutralisation.

What is the molar mass of the acid?

(A) 31.5 g mol^{-1}

(B) 63.0 g mol^{-1}

(C) 98.0 g mol^{-1}

(D) 126 g mol^{-1}

Chemistry NESA No: _____

Section II

80 marks
Attempt Questions 21–35
Allow about 2 hours and 25 minutes for this section

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations and graphs.

Question 21 (4 marks)

Students modelled chemical equilibrium using the following physical system.

1. Place two beakers side by side.
2. Label the beakers A and B.
3. Add 200 M&Ms to beaker A.
4. Record the number of M&Ms in each beaker.
5. Transfer 20% of the M&Ms in beaker A to beaker B.
6. Transfer 10% of the M&Ms in beaker B to beaker A.
7. Repeat steps 4-6 until there is no more change in the number of M&Ms.

(a) Discuss the strengths and weaknesses of this procedure as a model for chemical equilibrium. **3**

(b) Describe a change to this procedure that would model how equilibrium is affected by catalysis. **1**

Question 22 (6 marks)

Sulfur dioxide and oxygen can be reacted to form sulfur trioxide according to the equation:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

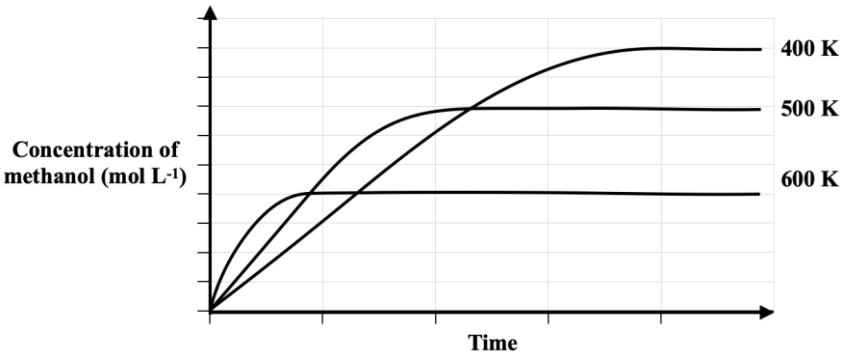
(a) Use Le Chatelier's Principle to predict any changes in the equilibrium position if the volume of the reaction vessel is increased. Justify your response. **3**

(b) Explain these changes using collision theory. **3**

Question 23 (7 marks)

Hydrogen and carbon monoxide react as gases as follows:

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$



(a) Write the equilibrium expression for this reaction. **1**

(b) State one way that the equilibrium constant for this reaction could be increased and justify your choice. **2**

(c) 1.0 mol of H_2 and 1.0 mol of CO were placed into a 4.0 L container at 298 K. When the system had reached equilibrium, it was found that 0.2 mol of CH_3OH had been formed. **2**

Calculate the equilibrium constant for the reaction under these conditions.

Question 23 continues on page 15

Question 23 (continued)

(d) A 10 L vessel contains 2.5 mol of H_2, 4.0 mol of CO and 3.0 mol of CH_3OH at 298 K. Is this system at equilibrium, and if not, which direction will the reaction shift to achieve equilibrium? **2**

Question 24 (4 marks)

K_w (the ionisation constant of water) is 5.50×10^{-13} at 375 K.

(a) Calculate the pH of water at this temperature. **2**

(b) Deduce whether the auto-ionisation of water is an exothermic or endothermic process. **2**

Justify your answer.

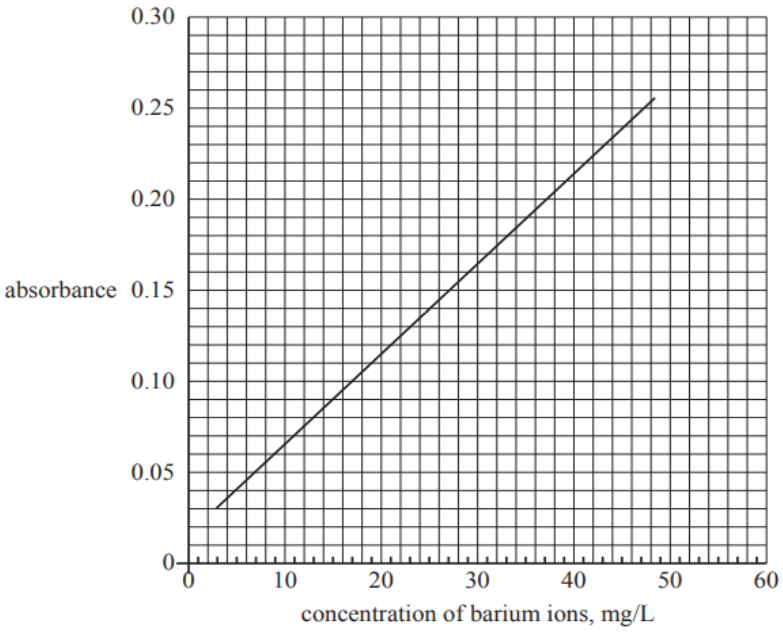
Question 25 (8 marks)

Elemental sulfur can be used to control outbreaks of powdery mildew on grapes. However, sulfur remaining on the grapes after harvest can be converted to a number of undesirable compounds during fermentation in wine production. A wine chemist uses atomic absorption spectroscopy to determine the amount of sulfur remaining on grapes.

In a particular analysis, 100.0 g of grapes were treated with 100.0 mL of surfactant solution to remove the sulfur remaining on the grapes when they were harvested. 25.00 mL of this surfactant solution was treated to convert all of the sulfur to sulfate ions and then dried to produce an ash containing the sulfate ions. This ash was transferred to a 10.00 mL volumetric flask containing 2.00 mL of 200 mg/L solution of barium Ba^{2+} ions. The volume of solution in the volumetric flask was then made up to the calibration line. A precipitate of $BaSO_4$ formed and settled to the bottom of the volumetric flask.

A small amount of the solution containing the unreacted Ba^{2+} ions was removed from the volumetric flask and analysed using atomic absorption spectroscopy. This solution gave an absorbance of 0.11.

A calibration curve was prepared using standard solutions of 10, 20, 30 and 40 mg/L $Ba^{2+}(aq)$.



(a) Determine the **mass** of barium ions, in mg, remaining in the 10.00 mL sample solution. **2**

Question 25 continues on page 17

Question 25 (continued)

(b) Determine the amount of barium ions, in moles, that reacted to produce the barium sulfate precipitate. **2**

(c) Calculate the mass of sulfur, in mg, remaining on the 100.0 g of harvested grapes. **2**

(d) The amount of sulfur remaining on the grapes can also be determined using gravimetric analysis. Explain two reasons why atomic absorption spectroscopy is a better way to determine the residual sulfur on the grapes, compared to gravimetric analysis. **2**

Question 26 (7 marks)

A solution of oxalic acid ($C_2H_2O_4$), a weak diprotic acid, was prepared by dissolving 5.630 g in 250.0 mL water. This was used to standardise a sodium hydroxide solution.

(a) Calculate the concentration of the oxalic acid solution. **2**

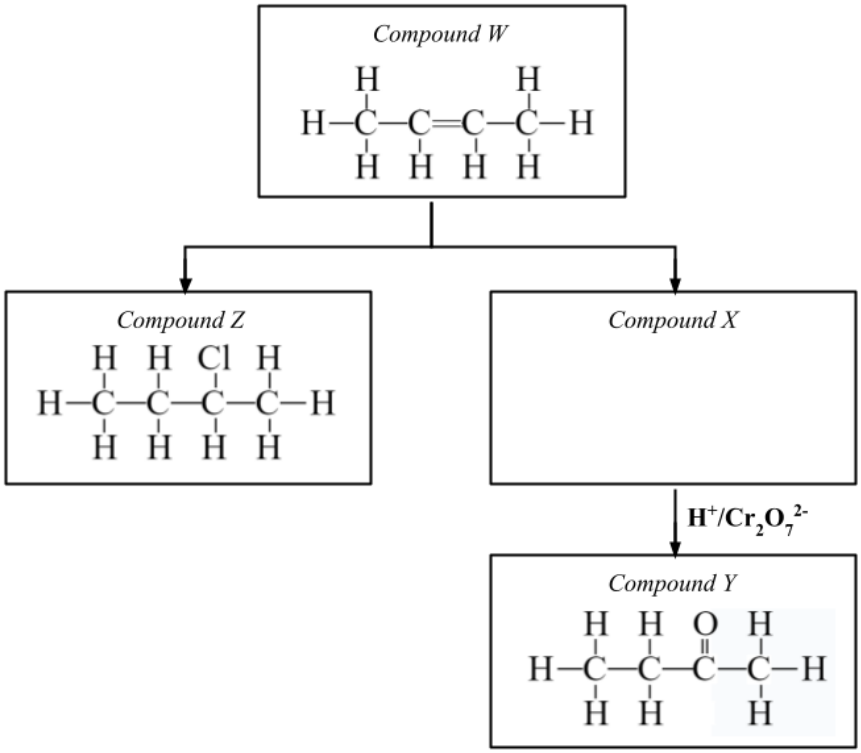
(b) With reference to TWO properties of oxalic acid, explain why it is suitable for use as a primary standard. **2**

(c) A number of 25.00 mL aliquots of the oxalic acid solution were titrated against the sodium hydroxide, with an average titre of 13.65 mL. **3**

Calculate the concentration of the sodium hydroxide solution.

Question 27 (5 marks)

Consider the reactions below:



(a) Name and draw the structural formula of compound X. **2**

Name:

(b) Identify the name of compound Z. **1**

.....

(c) Draw the reaction of compound W with bromine water, using structural formulae, and name the product formed. **2**

Question 28 (4 marks)

A buffer solution has the property of resisting change in pH even when small amounts of acid or alkali are added to it.

Using equilibrium principles, compare the change in pH of a 1:1 molar solution of $CaCl_2$/HCl and a 1:1 molar solution of $NaH_2PO_4^-/Na_2HPO_4$ when a small amount of acid is added to each mixture.

4

Question 29 (5 marks)

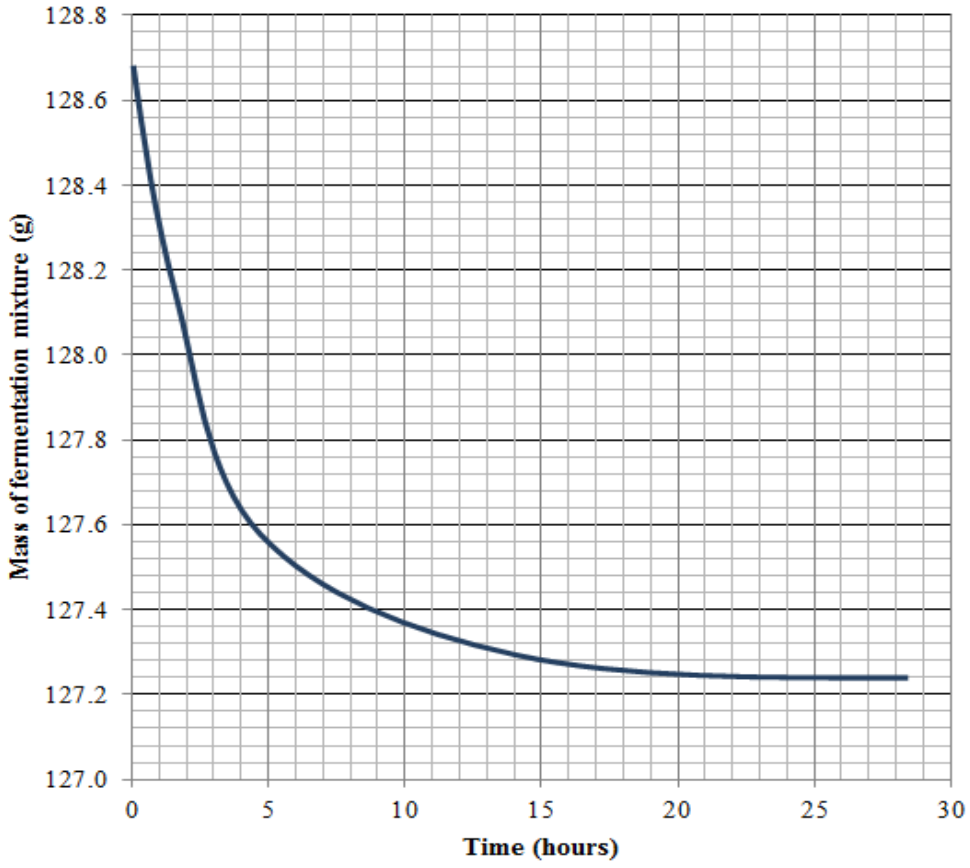
The production of alcohol can be achieved in a school laboratory by the fermentation of glucose according to the equation below.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{yeast}} 2C_2H_5OH(aq) + 2CO_2(g)$$

A student added 12 g of glucose to a conical flask along with 1 g of yeast and 50 mL of water at 37°C.

The conical flask was placed on a balance that was connected to a computer to monitor mass changes in the reaction vessel.

The graph below shows how the mass of the reaction mixture changed over a 24 hour period.



(a) Calculate the mass change in the conical flask by referring to the graph.

1

.....

.....

Question 29 continues on page 22

Question 29 (continued)

(b) Calculate the mass of ethanol produced by the reaction and compare this to a theoretical yield of ethanol. Show all working. **4**

Question 30 (3 marks)

The *white smoke reaction* is a neutralisation reaction between the vapours of concentrated solutions of hydrochloric acid and ammonia. It is given its name due to the production of fine white salt crystals that are momentarily suspended in the air when vapours react, giving the appearance of white smoke.

Justify why this reaction can only be explained by the Brønsted-Lowry definition of acids and bases, and not the Arrhenius definition. Include a chemical equation in your answer. **3**

Question 31 (8 marks)

The properties of three organic compounds, Q, R and S, are given in the table.

Compound	*Q*	*R*	*S*
Formula	CH_3CH_2COOH	$CH_3CH_2CH_2CH_2NH_2$	$CH_3CH_2CONH_2$
Molecular weight	74.08	73.14	73.09
Boiling point (°C)	141.2	78	213
pKa	4.88	10.21	

(a) Name the three compounds tabulated above. **3**

Q:

R:

S:

(b) Write TWO equations to compare the reactions that occur when compounds Q and R are individually added to water. **2**

(c) Provide reasons for the variation in boiling points between the three compounds described above, given that all have very similar molecular weights. **3**

Question 32 (4 marks)

Four 0.1M solutions of silver nitrate, lead nitrate, iron (III) nitrate and potassium nitrate are contained in separate, unlabelled bottles. Describe a series of laboratory tests that would successfully identify these solutions. Where appropriate, provide supporting chemical equations and predicted observations.

4

Question 33 (6 marks)

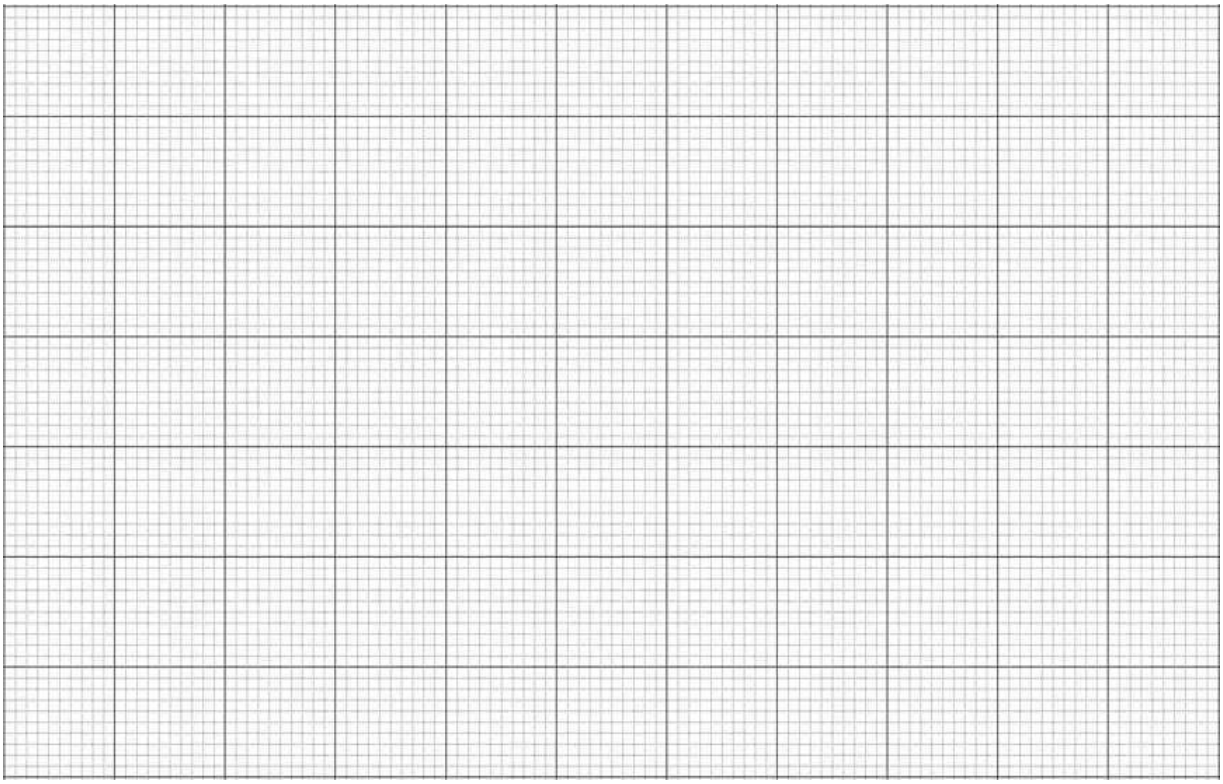
A conductivity titration was performed to determine the concentration of a hydrochloric acid solution. A 25.0 mL sample of the acid was placed into a conductivity cell.

A burette was then used to slowly dispense volumes of 0.500 mol L^{-1} sodium hydroxide.

Conductivity readings were taken per 1 mL of sodium hydroxide added. Data was recorded in the following table.

Vol 0.5 mol L^{-1} NaOH (mL)	0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Conductivity (S cm^{-1})	3.4	3.1	2.6	2.1	1.8	1.4	1.1	1.6	1.8	2.3	2.7

Graph the data in the table using intersecting lines of best fit and perform relevant calculations to determine the concentration of the hydrochloric acid solution. **6**



Question 33 continues on page 27

Question 33 (continued)

Question 34 (4 marks)

Compare the structures, properties and uses of TWO named addition polymers.

4

Question 35 (5 marks)

A 40.0 mL solution of 2.00×10^{-3} mol L^{-1} sodium sulfate is added to 200 mL solution of 2.00×10^{-3} mol L^{-1} lead (II) nitrate. Perform calculations to determine whether a precipitate of lead (II) sulfate will form.

5

Section II extra writing space

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Section II extra writing space

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NESA Student number

2023
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Chemistry

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Total marks – 100

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Section I
20 marks

Attempt Questions 1–20
Allow about 35 minutes for this part

Use the separate multiple-choice answer sheet for Questions 1–20

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1. The forward reaction in the equilibrium shown is endothermic.

$$OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$$

Which change increases the concentration of the hypochlorous acid (HOCl)?

(A) Adding water

(B) Adding sodium hypochlorite, NaOCl(s)

(C) Adding hydroxide ions

(D) Lowering the temperature

2. 0.1 moles of each of the following substances is dissolved in 1 L of water. For which substance would the pH of the solution be the closest to 14?

(A) $Ca(OH)_2$

(B) CH_3CH_2OH

(C) NH_4Cl

(D) $NaCH_3COO$

3. A saturated solution of $BaSO_4$ is maintained at constant temperature. Solid soluble Na_2SO_4 is added to this solution. What happens to the Ba^{2+} and SO_4^{2-} ion concentrations in the resultant solution compared to the initial solution?

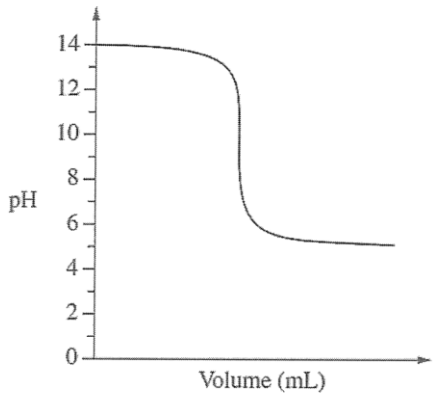
(A) Ba^{2+} concentration increases and SO_4^{2-} concentration remains the same

(B) Ba^{2+} concentration increases and SO_4^{2-} concentration increases

(C) Ba^{2+} concentration decreases and SO_4^{2-} concentration increases

(D) Ba^{2+} concentration decreases and SO_4^{2-} concentration remains the same

4. The graph shows the changes in pH during a titration



Which indicator should be chosen for this titration?

(A) Methyl orange (pH range 3.1 – 4.4)

(B) Bromocresol green (pH range 4.5 – 5.2)

(C) Bromothymol blue (pH range 6.0 – 7.6)

(D) Phenolphthalein (pH range 8.3 – 10.0)

5. Which of these substances is an example of a polyprotic acid?

(A) HCl

(B) HNO_3

(C) H_3CrO_4

(D) CH_3COOH

6. Below is an equation for a reversible reaction.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

The reaction's correct equilibrium expression is:

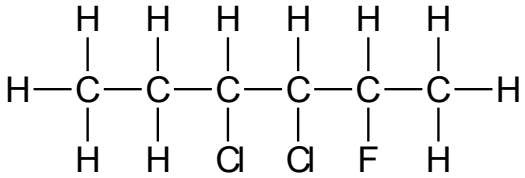
(A) $\frac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}][H^+]}$

(B) $\frac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}]^2[H^+]^2}$

(C) $\frac{[Cr_2O_7^{2-}][H_2O]}{[CrO_4^{2-}]^2[H^+]^2}$

(D) $\frac{[CrO_4^{2-}]^2[H^+]^2}{[Cr_2O_7^{2-}]}$

7. What is the IUPAC name of the following compound?



(A) 5-fluoro-3,4-dichlorohexane

(B) 2-fluoro-3,4-dichlorohexane

(C) 3,4-dichloro-5-fluorohexane

(D) 3,4-dichloro-2-fluorohexane

8. Chlorine gas (Cl_2) and carbon monoxide gas (CO) are placed in a sealed container and kept at a temperature of 25°C. Phosgene gas is produced as follows:

$$Cl_2(g) + CO\ (g) \rightleftharpoons COCl_2(g)$$

Which statements about this reaction are correct?

(A) All the Cl_2 and CO will be converted into $COCl_2$

(B) At a temperature of 25°C the $COCl_2$ will not form

(C) The forward reaction will continue to occur until the concentration of $COCl_2$ remains constant

(D) When the forward and reverse reactions become equal the concentration of $COCl_2$ becomes constant

9. The molar masses of C_2H_6, CH_3OH and CH_3F are similar. Which of the following lists these compounds in order of increasing boiling point?

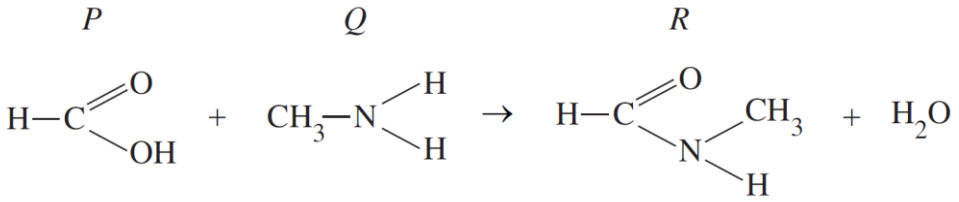
(A) $C_2H_6 < CH_3OH < CH_3F$

(B) $C_2H_6 < CH_3F < CH_3OH$

(C) $CH_3F < CH_3OH < C_2H_6$

(D) $CH_3OH < CH_3F < C_2H_6$

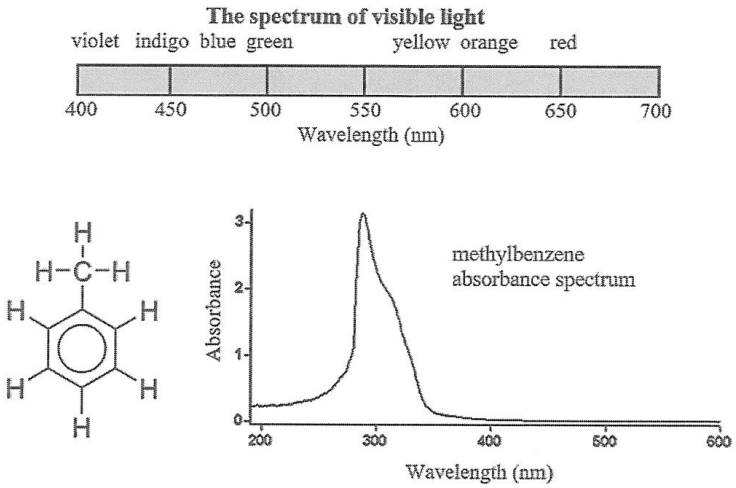
10. The diagram below shows molecules P and Q reacting to form R and water.



Which row of the table correctly identifies the molecule types?

	P	*Q*	*R*
(A)	carboxylic acid	amine	amide
(B)	carboxylic acid	amide	amine
(C)	alcohol	amine	ester
(D)	aldehyde	amide	ketone

11. The spectrum of visible light, structural formula and UV absorption spectrum of methylbenzene is shown.



Based on the information, which statement about methylbenzene is correct?

(A) A solution of methylbenzene would appear colourless

(B) A solution of methylbenzene would appear as an orange-red colour

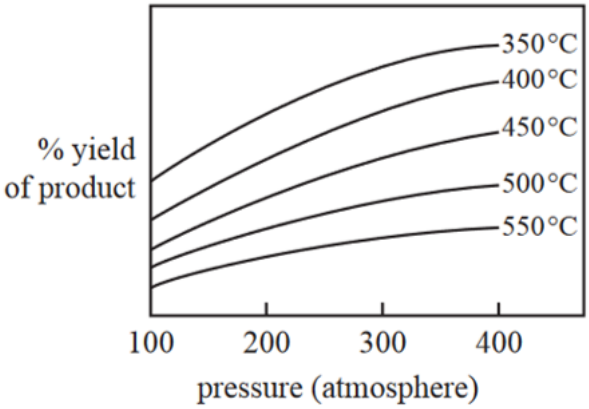
(C) Methylbenzene only absorbs in the visible part of the electromagnetic spectrum

(D) Methylbenzene does not absorb wavelengths lower than 100 nm

12. The graph below refers to the following gaseous reaction.

$$aA(g) + bB(g) \rightleftharpoons cC(g) + dD(g)$$

The effect of increasing pressure and temperature on the equilibrium yield of products is shown in the graph below.



Which of the following alternatives regarding the equilibrium systems is consistent with the data above?

	Relative numbers of moles of products and reactants	*ΔH*
(A)	a + b < c + d	-
(B)	a + b < c + d	+
(C)	a + b > c + d	-
(D)	a + b > c + d	+

13. Which of the following pairs of compounds will form a precipitate when 0.1 mol L^{-1} solutions of each are mixed?

(A) $AgNO_3$ and $Ba(NO_3)_2$

(B) K_2SO_4 and $Cu(NO_3)_2$

(C) $Ca(NO_3)_2$ and KBr

(D) NaOH and $CuCl_2$

14. A student performed a titration to determine the concentration of an unknown sodium hydroxide solution using a standard solution of hydrochloric acid. They performed the following steps:

- A burette was rinsed with deionised water, then rinsed again with the sodium hydroxide solution.
- The burette was then filled with the sodium hydroxide solution.
- A volumetric pipette and a conical flask were both washed with deionised water, then washed again with the hydrochloric acid solution.
- 25 mL of the hydrochloric acid solution was transferred into the conical flask using the pipette and an appropriate indicator added.
- Titration performed until the endpoint, and the titrant volume recorded.

The accuracy of the student's value was determined by comparing it to the true value. The calculated concentration based on the method described above will be:

(A) Higher than the true value

(B) Lower than the true value

(C) The same as the true value

(D) Different than the true value, but there is insufficient information to determine if it would be higher or lower

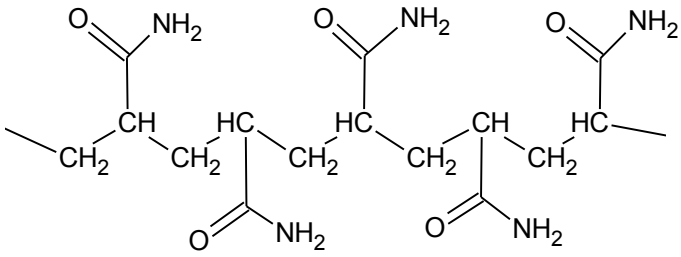
15. Four organic compounds are identified by the numbers I, II, III, IV.

I – CH_3CH_2COOH
II – CH_3CH_2OH
III – $CH_3CH2CONH_2$
IV – $CH_3CH_2NH_2$

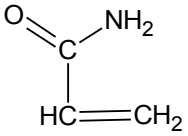
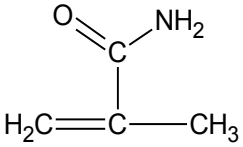
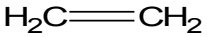
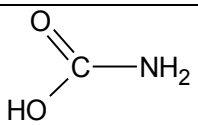
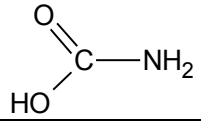
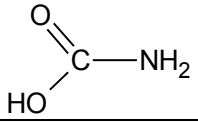
Which alternative identifies the strongest acid and strongest base in the list?

	Strongest acid	*Strongest base*
(A)	I	III
(B)	I	IV
(C)	II	III
(D)	II	IV

16. The diagram below shows a polymer.



Identify the type of polymerisation reaction used to produce it and the monomer or monomer units used to make it.

	Type of polymerisation	*Monomer 1*	*Monomer 2*
(A)	Addition		N/A
(B)	Addition		N/A
(C)	Condensation		
(D)	Condensation		

17. What is the function of the hollow cathode lamp in an atomic absorption spectrometer?

(A) Provide a specific wavelength of light that can be absorbed by free atoms in the gaseous state

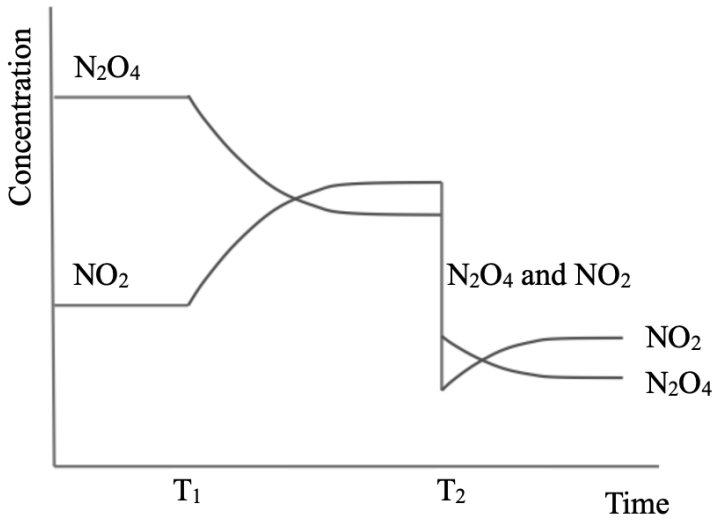
(B) Separate molecules in the tested sample so that free atoms are formed

(C) Convert free atoms in the tested sample into gaseous ions

(D) Produce a frequency of light that is absorbed by particular bonds of molecules in the sample being tested

18. The graph shows the concentrations over time for the equilibrium system:

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58 \text{ kJ.mol}^{-1}$$



What has happened to the temperature at T_1 and to the volume at T_2?

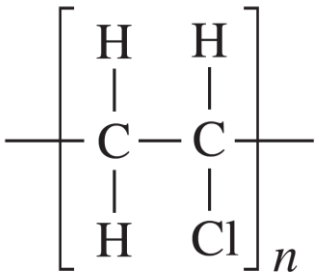
(A) Temperature ***decreased*** at T_1 and volume ***increased*** at T_2

(B) Temperature ***increased*** at T_1 and volume ***decreased*** at T_2

(C) Temperature ***decreased*** at T_1 and volume ***decreased*** at T_2

(D) Temperature ***increased*** at T_1 and volume ***increased*** at T_2

19. A researcher was examining a sample of the polymer polyvinyl chloride (PVC) to determine its chain length. The sample was found to have a molar mass of 623 800 g mol^{-1}. A section of the chain is shown.



What is the value of n?

(A) 789.8

(B) 2494

(C) 9982

(D) 155 950

20. 1.23 g of a pure acid, $H_2X(s)$, is added to exactly 250.0 mL of 0.100 M NaOH(aq).

$$H_2X(s) + 2NaOH(aq) \rightarrow Na_2X(aq) + 2H_2O(l)$$

The NaOH is in excess. This excess NaOH requires 27.50 mL of 0.20 M HCl(aq) for neutralisation.

What is the molar mass of the acid?

(A) 31.5 g mol^{-1}

(B) 63.0 g mol^{-1}

(C) 98.0 g mol^{-1}

(D) 126 g mol^{-1}

2023 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry NESA No: _____

Section II

80 marks
Attempt Questions 21–35
Allow about 2 hours and 25 minutes for this section

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations and graphs.

Question 21 (4 marks)

Students modelled chemical equilibrium using the following physical system.

1. Place two beakers side by side.
2. Label the beakers A and B.
3. Add 200 M&Ms to beaker A.
4. Record the number of M&Ms in each beaker.
5. Transfer 20% of the M&Ms in beaker A to beaker B.
6. Transfer 10% of the M&Ms in beaker B to beaker A.
7. Repeat steps 4-6 until there is no more change in the number of M&Ms.

(a) Discuss the strengths and weaknesses of this procedure as a model for chemical equilibrium. **3**

Criteria	Marks
• Correctly describes at least 3 strengths and weaknesses (at least one of each)	3
• Correctly describes one strength AND one weakness	2
• Describes one strength OR one weakness	1

(b) Describe a change to this procedure that would model how equilibrium is affected by catalysis. **1**

Criteria	Marks
• Describes an appropriate change.	1

Question 22 (6 marks)

Sulfur dioxide and oxygen can be reacted to form sulfur trioxide according to the equation:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(a) Use Le Chatelier's Principle to predict any changes in the equilibrium position if the volume of the reaction vessel is increased. Justify your response. **3**

Criteria	Marks
• Correctly predicts the change in the direction of the reaction • States why this change will occur • Supports response with clear reference to Le Chatelier's Principle	3
• Correctly predicts the change in the direction of the reaction • States why this change will occur	2
• Provides some relevant information	1

Sample answer:

Le Chatelier's Principle states that if a system at equilibrium is disturbed, then the system will adjust itself to minimise the disturbance and return to equilibrium. Decreasing the overall pressure of the system will lead to a decrease in the concentration of all gases. The reaction will shift to the left, favouring the reverse reaction, as this is the direction which forms the most gas and that will lead to an increase in the overall system pressure.

(b) Explain these changes using collision theory. **3**

Criteria	Marks
• Explains changes that occur in the reaction • Links change to increased volume as a result of pressure change • Supports response with clear reference to collision theory	3
• Explains changes that occur in the reaction • Links change to increased volume as a result of pressure change	2
• Provides some relevant information	1

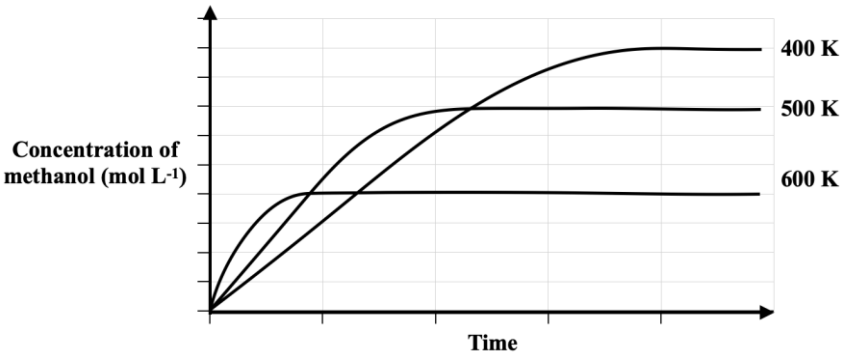
Sample answer:

Collision theory states that for a reaction to occur, the particles must collide with sufficient energy to break the bonds and have the appropriate orientation to allow the new bonds to form. Decreasing the system pressure leads to an increase in its volume. The gas molecules have more space in which they can move around. This decreases the chance that successful collisions will occur, and this prevents the forward reaction from proceeding.

Question 23 (7 marks)

Hydrogen and carbon monoxide react as gases as follows:

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$



(a) Write the equilibrium expression for this reaction. **1**

Criteria	Marks
• Correct expression given	1

Sample answer:

$$K = \frac{[CH_3OH]}{[H_2]^2[CO]}$$

(b) State one way that the equilibrium constant for this reaction could be increased and justify your choice. **2**

Criteria	Marks
• Correctly identifies decreasing temperature as a means of increasing K • Provides a justification	2
• Correctly identifies decreasing temperature as a means of increasing K	1

Sample answer:

The value of the equilibrium constant Keq can only be altered by changes in temperature. Given that the forward reaction is exothermic, a decrease in the reaction temperature would shift the equilibrium in the forward direction, to produce more heat and counteract the temperature change. This would increase the concentration of products, resulting in an increase in the value of Keq.

Markers comments:

A number of students identified changes that would cause a shift to favour products, however, these alterations would not change the equilibrium **constant**. Only temperature will alter this value.

(c) 1.0 mol of H_2 and 1.0 mol of CO were placed into a 4.0 L container at 298 K. When the system had reached equilibrium, it was found that 0.2 mol of CH_3OH had been formed. **2**

Calculate the equilibrium constant for the reaction under these conditions.

Criteria	Marks
• Correctly calculates equilibrium concentrations of all species • Correctly determines value of Keq	2
• Calculates equilibrium concentrations of all species, • OR both of the above, with minor errors	1

Sample answer:

	$[H_2]$	[CO]	$[CH_3OH]$
I	0.25	0.25	0
C	–0.1	–0.05	+0.05
E	0.15	0.2	0.05

$$K_{eq} = \frac{0.05}{(0.15)^2(0.2)} = 11.1$$

(d) A 10 L vessel contains 2.5 mol of H_2, 4.0 mol of CO and 3.0 mol of CH_3OH at 298 K. Is this system at equilibrium, and if not, which direction will the reaction shift to achieve equilibrium? **2**

Criteria	Marks
• Correctly calculates equilibrium concentrations of all species • Determines value of Q and compares to Keq to identify shift	2
• Calculates value for Q • Or, both of the above, with minor error	1

Sample answer:

$$Q = \frac{0.3}{(0.25)^2 \times 0.4} = 12$$

$Q > K \therefore$ not at equilibrium, reaction will shift left towards the reactants

Question 24 (4 marks)

K_w (the ionisation constant of water) is 5.50×10^{-13} at 375 K.

(a) Calculate the pH of water at this temperature. **2**

Marking Criteria	Marks
• Calculates the pH of water at 373K	**2**
• Provides one step in the calculation or writes the expression of K_w	**1**

Sample answer:

$K_w = [H_3O^+] \times [OH^-] = 5.50 \times 10^{-13}$ (at 373K)

$[H_3O^+] = \sqrt{5.50x10^{-13}}$

$= 7.45 \times 10^{-7}$

$pH = -\log [H_3O^+]$

$= -\log 7.45 \times 10^{-7}$

$= 6.13$

(b) Deduce whether the auto-ionisation of water is an exothermic or endothermic process. **2**

Justify your answer.

Marking Criteria	Marks
• Deduces the endothermic nature of the self-ionisation of water by comparing the size of K_w at 273K and 373K and by applying knowledge of Le Chatelier's Principle and the nature of K.	**2**
• Provides some relevant information.	**1**

Sample answer:

Higher temperatures favour the endothermic reaction in an equilibrium system, as the endothermic reaction absorbs some heat from the environment and thereby minimises the effect of the higher temperature (by Le Chatelier's Principle).

Since the value of K_w at 373K is higher than that at 273K (1.0×10^{-14}), the higher temperatures must have favoured the forward reaction, increasing the $[H_3O^+]$ and $=[OH^-]$, as this would increase K (products/reactants).

Therefore the data suggests the self-ionisation of water is an endothermic process.

Markers comments:

Students needed to be specific when justifying, such as providing information about the Kw or hydrogen ion concentration at both temperatures (not just that Kw is 'high' or 'low' at a certain temperature).

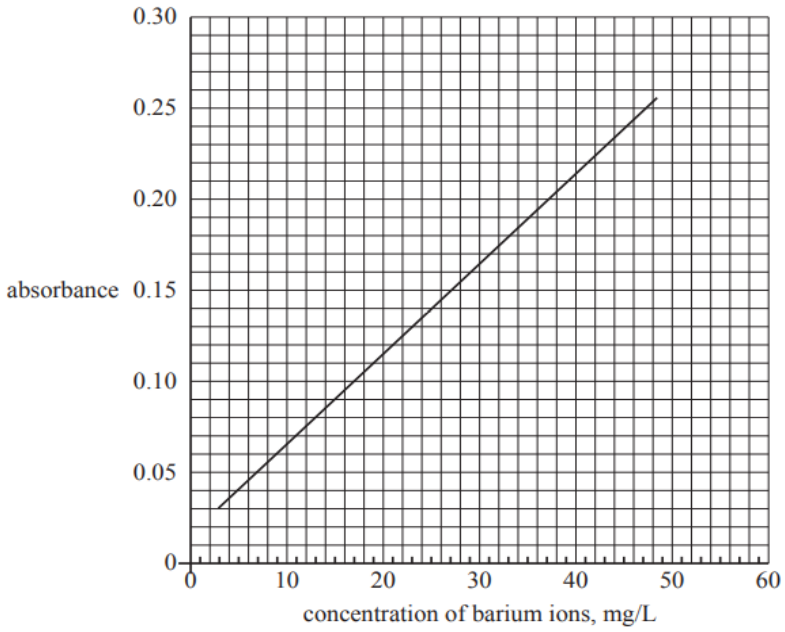
Question 25 (8 marks)

Elemental sulfur can be used to control outbreaks of powdery mildew on grapes. However, sulfur remaining on the grapes after harvest can be converted to a number of undesirable compounds during fermentation in wine production. A wine chemist uses atomic absorption spectroscopy to determine the amount of sulfur remaining on grapes.

In a particular analysis, 100.0 g of grapes were treated with 100.0 mL of surfactant solution to remove the sulfur remaining on the grapes when they were harvested. 25.00 mL of this surfactant solution was treated to convert all of the sulfur to sulfate ions and then dried to produce an ash containing the sulfate ions. This ash was transferred to a 10.00 mL volumetric flask containing 2.00 mL of 200 mg/L solution of barium Ba^{2+} ions. The volume of solution in the volumetric flask was then made up to the calibration line. A precipitate of $BaSO_4$ formed and settled to the bottom of the volumetric flask.

A small amount of the solution containing the unreacted Ba^{2+} ions was removed from the volumetric flask and analysed using atomic absorption spectroscopy. This solution gave an absorbance of 0.11.

A calibration curve was prepared using standard solutions of 10, 20, 30 and 40 mg/L $Ba^{2+}(aq)$.



(a) Determine the **mass** of barium ions, in mg, remaining in the 10.00 mL sample solution. **2**

Criteria	Marks
• Estimates that the $[Ba^{2+}]$ is 19 mg/L (from graph). • Calculates that mass of Ba^{2+} in 10 mL is 0.19 mg.	2
• Estimates that the $[Ba^{2+}]$ is 19 mg/L (from graph).	1

Sample answer

From the graph, $[Ba^{2+}]$ remaining = 19 mg L^{-1}
Mass Ba^{2+} in 10.00 mL = (19 / 1000) x 10 mg = 0.19 mg

(b) Determine the amount of barium ions, in moles, that reacted to produce the barium sulfate precipitate. **2**

Criteria	Marks
• Calculates the no. of moles of Ba^{2+} that reacted to produce the barium sulfate precipitate.	2
• Calculates the mass of Ba^{2+} that reacted to produce the barium sulfate precipitate.	1

Sample answer

mass Ba^{2+} added to volumetric flask = (2.00 / 1000) x 200 = 0.400 mg

mass Ba^{2+} remaining in volumetric flask = 0.19 mg

mass Ba^{2+} reacted = 0.400 – 0.19 = 0.21 mg = 0.00021 g

No. of moles Ba^{2+} reacted = $0.21 \times 10^{-3} / 137.3 = 1.5 \times 10^{-6}$ mol

(c) Calculate the mass of sulfur, in mg, remaining on the 100.0 g of harvested grapes. **2**

Criteria	Marks
• Calculates the no. of moles of sulfur in 25 mL surfactant. **AND** • Calculates the mass of sulfur, in mg, on the 100.0 g of grapes.	2
• Calculates the no. of moles of sulfur in 25 mL surfactant.	1

Sample answer

n(S) in 25 mL surfactant = n($BaSO_4$) precipitated in volumetric flask

= n(Ba^{2+}) reacted = 1.5×10^{-6} mol

n(S) in 100.0 g of grapes = n(S) in 100 mL surfactant = $4 \times 1.5 \times 10^{-6} = 6.0 \times 10^{-6}$ mol

m(S) in 100.0 g of grapes = $6.0 \times 10^{-6} \times 32.1 = 1.9 \times 10^{-4}$ g = 0.19 mg

(d) The amount of sulfur remaining on the grapes can also be determined using gravimetric analysis. Explain two reasons why atomic absorption spectroscopy is a better way to determine the residual sulfur on the grapes, compared to gravimetric analysis. **2**

Criteria	Marks
• Explains TWO reasons why AAS is a better way of determining the amount of S left on grapes than gravimetric analysis.	2
• Explains ONE reason why AAS is a better way of determining the amount of S left on grapes than gravimetric analysis. • OR, provides TWO well described limitations of gravimetric analysis without appropriate reference to how AAS overcomes	1

Sample answer:

Gravimetric analysis is less accurate than AAS when very small quantities are to be precipitated and weighed.

The percentage error due to loss of solid during precipitation, filtering, weighing and drying is likely to be greater in gravimetric analysis than in an instrumental analysis which is very sensitive, in that small concentrations can be detected and measured against standards.

A large mass of grapes is needed for effective gravimetric analysis, whereas only a small but representative sample is needed for AAS analysis.

Markers comments:

Q25 was poorly done overall, there was confusion about conversions between mg and g. Many students were confused in what was being done at each step/what information the question was asking for. Read question thoroughly to understand process in stimulus, ensure you provide information as requestion (e.g. if asked for mg, give mg – not g, mol etc)

Question 26 (7 marks)

A solution of oxalic acid ($C_2H_2O_4$), a weak diprotic acid, was prepared by dissolving 5.630 g in 250.0 mL water. This was used to standardise a sodium hydroxide solution.

(a) Calculate the concentration of the oxalic acid solution. **2**

Criteria	Marks
• Determine the number of moles of oxalic acid • Determines the concentration of oxalic acid solution to 4 s.f.	2
• Determines the number of moles of oxalic acid • OR, both of the above with minor errors	1

Sample answer:

$n = m/mm$

$= 5.63g/90.036gmol^{-1}$

$= 0.0625mol$

$c = n/v$

$= 0.0625mol/0.2500L$

$= 0.2501molL^{-1}$

(b) With reference to TWO properties of oxalic acid, explain why it is suitable for use as a primary standard. **2**

Criteria	Marks
• Provides two properties of oxalic acid and thoroughly describes how these make it suitable for use as a primary standard	2
• Provides one property of oxalic acid and thoroughly describes how these make it suitable for use as a primary standard • OR, provides two properties and gives some explanation on how they make it suitable for use as a primary standard	1

Sample answer:

It is chemically stable so the concentration will not change over time.

It is a solid with a high molecular mass so it is easily weighed with a relatively small uncertainty in the number of moles.

(c) A number of 25.00 mL aliquots of the oxalic acid solution were titrated against the sodium hydroxide, with an average titre of 13.65 mL. **3**

Calculate the concentration of the sodium hydroxide solution.

Criteria	Marks
• Provides a balanced chemical equation • Calculates number of moles of oxalic acid and sodium hydroxide • Determines concentration of sodium hydroxide solution	3
• Two of the above	2
• One of the above	1

Sample answer:

$C_2H_2O_4(aq) + 2NaOH(aq) \rightarrow (COONa)_2(aq) + 2H_2O(l)$

$n(C_2H_2O_4) = 0.250 molL^{-1} \times 0.025L$

$= 6.25 \times 10^{-3} mol$

$n(C_2H_2O_4):n(NaOH) = 1:2$

$n(NaOH) = 2 \times 6.25 \times 10^{-3} mol$

$= 0.0125 mol$

$c = n/v$

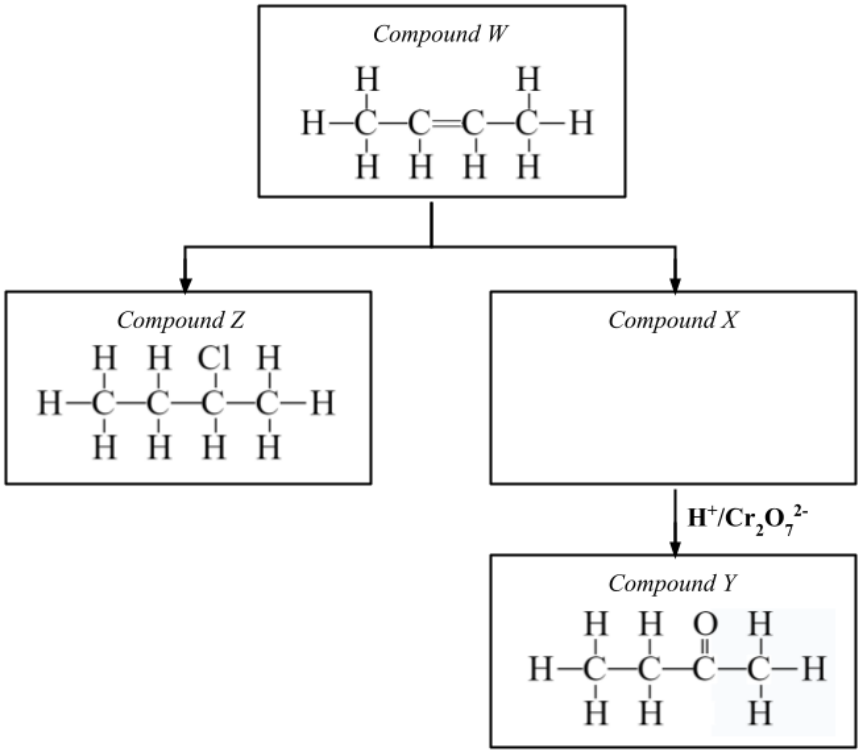
$= 0.0125 mol/0.01365L$

$= 0.91575 molL^{-1}$

$= 0.916 molL^{-1}$

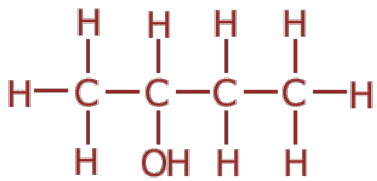
Question 27 (5 marks)

Consider the reactions below:



(a) Name and draw the structural formula of compound X. **2**

Criteria	Marks
• Writes the correct structural formulae and name	2
• ONE of the above	1



Name: butan-2-ol

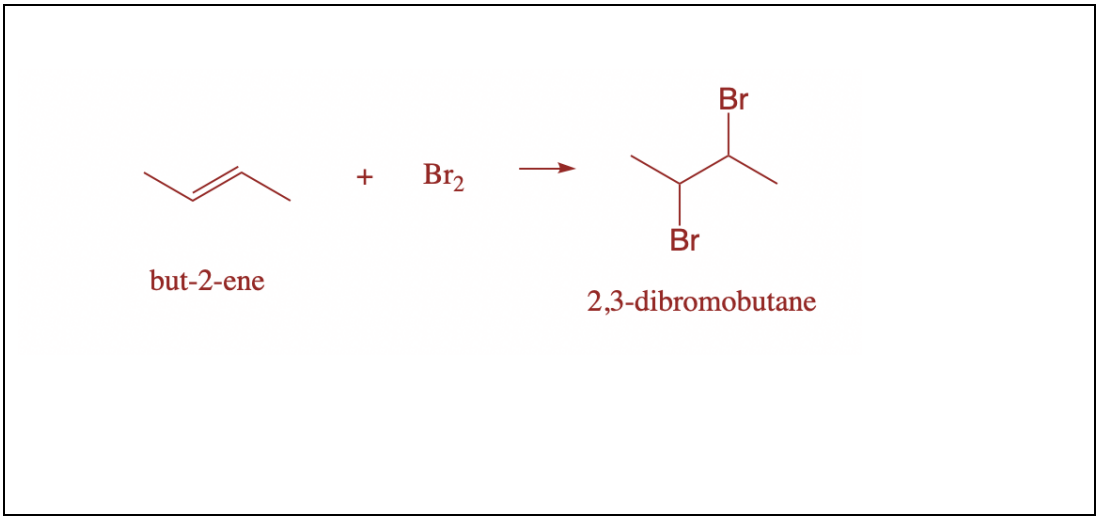
(b) Identify the name of compound Z. **1**

Criteria	Marks
• Writes the correct name	1

2-chlorobutane

(c) Draw the reaction of compound W with bromine water, using structural formulae, and name the product formed. **2**

Criteria	Marks
• Writes the correct equation using structural formulae and correctly names the organic product.	2
• Addresses ONE of the above	1



Question 28 (4 marks)

A buffer solution has the property of resisting change in pH even when small amounts of acid or alkali are added to it.

Using equilibrium principles, compare the change in pH of a 1:1 molar solution of $CaCl_2$/HCl and a 1:1 molar solution of $NaH_2PO_4^-/Na_2HPO_4$ when a small amount of acid is added to each mixture.

4

Criteria	Marks
• Makes a general statement summarising the buffering ability of the two pairs of reagents including requirement of conjugate pairs • Thoroughly compares the reactions of the ions $H_2PO_4^-$, HPO_4^{2-} and Cl^- with water, and relates these to their relative strengths as bases compared with water. • Includes an appropriate equation to illustrate the shift in equilibrium required to maintain the pH when an acid is added.	4
• Compares the reactions of the ions $H_2PO_4^-$, HPO_4^{2-} and Cl^- with water, and relates these to their relative strengths as bases compared with water. • Includes of an appropriate equation to illustrate the shift in equilibrium required to maintain the pH when an acid is added.	3
• Discusses the reactions of the ions $H_2PO_4^-$, HPO_4^{2-} only with water and relates these to their relative strengths as bases compared with water. OR • Discusses the reaction of the Cl^- ion with water and relates this to its relative strength as a base compared with water. AND • Includes an appropriate equation to illustrate the shift in equilibrium required to maintain the pH when an acid is added.	2
• Provides some relevant information	1

Sample answer:

The capacity of a solution to resist changes in pH upon addition of an acid or a base relies on the existence of compounds that can react with the acid or the base. Specifically, both an acid and a base must be present in the mixture to combine with any added base or acid and preserve the pH. In contrast, a strong acid like HCl, which fully ionises in an aqueous medium, generates a weak conjugate base, Cl^-, that cannot bind to any added acid (proton). Consequently, in the absence of a buffering system, an acid added to the $CaCl_2$/HCl solution will significantly decrease the pH.

The $NaH_2PO_4^-/Na_2HPO_4$ mixture exhibits an equilibrium between $H_2PO_4^-$ and HPO_4^{2-} ions in the presence of water, generating H_3O^+ ions according to the equation below:

$H_2PO_4^-\ (aq) + H_2O\ (l) \leftrightharpoons H_3O^+\ (aq) + HPO_4^{2-}\ (aq)$

In the case of the weak acid $H_2PO_4^-$, the proton remains bound to its conjugate base, the HPO_4^{2-} ion, until it encounters a stronger base, such as the OH^- ion, with which it combines.

In general, buffer solutions resist changes in pH by having both a weak acid and its conjugate base (or a weak base and its conjugate acid) present in the solution. The acid and its conjugate base can react with added H^+ or OH^- ions to maintain the pH of the solution within a certain range. In this example, the phosphate equilibrium is the only one that can act as a buffer.

Question 29 (5 marks)

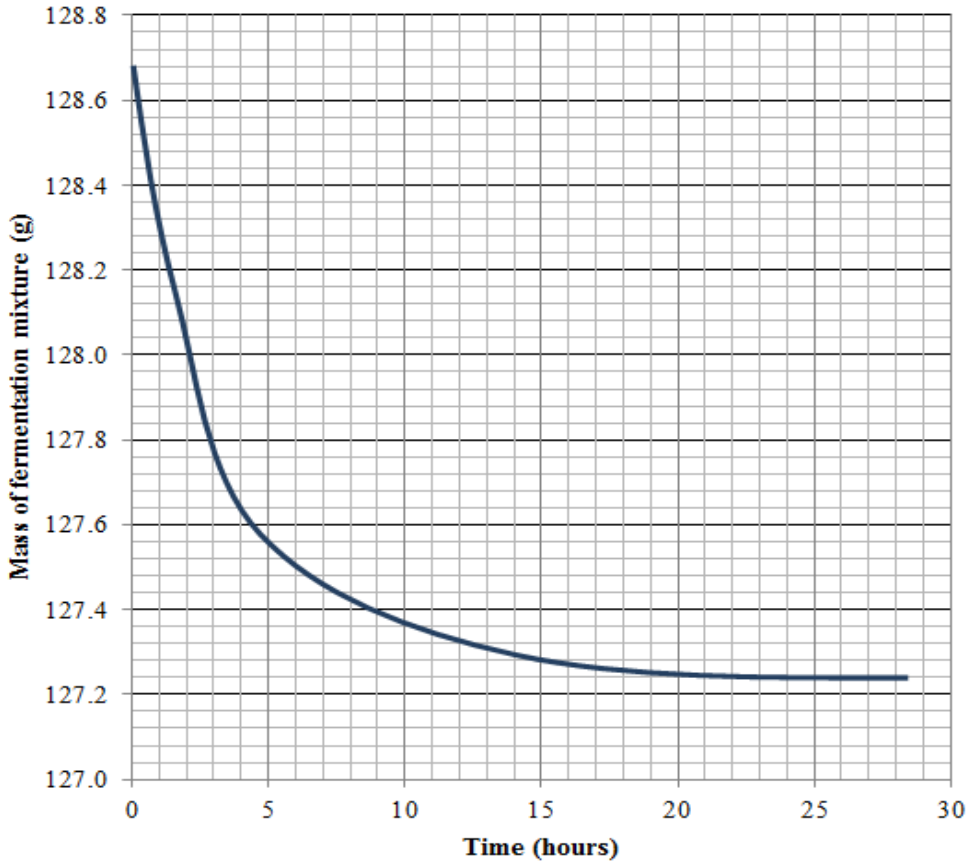
The production of alcohol can be achieved in a school laboratory by the fermentation of glucose according to the equation below.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{yeast}} 2C_2H_5OH(aq) + 2CO_2(g)$$

A student added 12 g of glucose to a conical flask along with 1 g of yeast and 50 mL of water at 37°C.

The conical flask was placed on a balance that was connected to a computer to monitor mass changes in the reaction vessel.

The graph below shows how the mass of the reaction mixture changed over a 24 hour period.



(a) Calculate the mass change in the conical flask by referring to the graph. **1**

Criteria	Marks
• Correctly calculates mass change from graph.	1

Sample answer:

128.68 g – 127.24 g = 1.44 g

(b) Calculate the mass of ethanol produced by the reaction and compare this to a theoretical yield of ethanol. Show all working. **4**

Criteria	Marks
• Correctly calculates moles of carbon dioxide using mass lost. • Calculates correct mass of ethanol produced • Calculates the theoretical yield of ethanol • Makes a comparison to the theoretical mass produced	4
• Addresses THREE of the above criteria	3
• Addresses TWO of the above criteria	2
• Addresses ONE of the above criteria	1

Sample Answer:

Actual mass of ethanol produced:

$$n(CO_2) = \frac{1.44\ g}{44.01\ g.mol^{-1}} = 0.032\ mol$$

$n(C_2H_5OH) = 0.0327\ mol$ (1:1 ratio)

$m(C_2H_5OH) = 0.0327\ mol \times 46.068\ g.mol^{-1} = 1.5\ g$

theoretical mass of ethanol produced:

$$n(C_6H_{12}O_6) = \frac{12\ g}{180.156\ g.mol^{-1}} = 0.0666\ mol$$

$n(C_2H_5OH) = 0.0666\ mol \times 2$ (1:2 ratio)

$= 0.1332\ mol$

$m(C_2H_5OH) = 0.1332\ mol \times 46.068\ g.mol^{-1} = 6.1\ g$

The actual mass of ethanol produced is *lower* than the theoretical mass of ethanol.

Markers comments:

Some students were confused as to the source of the lost mass and attributed this to the production of ethanol, not carbon dioxide (lost as it is gaseous).

Question 30 (3 marks)

The *white smoke reaction* is a neutralisation reaction between the vapours of concentrated solutions of hydrochloric acid and ammonia. It is given its name due to the production of fine white salt crystals that are momentarily suspended in the air when vapours react, giving the appearance of white smoke.

Justify why this reaction can only be explained by the Brønsted-Lowry definition of acids and bases, and not the Arrhenius definition. Include a chemical equation in your answer. **3**

Criteria	Mark
• Correctly justifies why the white smoke reaction is explained using the Brønsted-Lowry definition of acids and bases, while the Arrhenius definition cannot be used • Includes a correct chemical equation that describes the white smoke reaction	3
• Outlines a correct reason why the white smoke reaction is explained using the Brønsted-Lowry definition of acids and bases • Include a correct chemical equation that describes the white smoke reaction	2
• Provides a correct reason why the white smoke reaction occurs based on Brønsted-Lowry theory	1

Sample answer:

$$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(s)$$

The white smoke reaction involves a transfer of protons from the hydrochloric acid to the ammonia molecule resulting in the formation of the ammonium chloride salt. This process is explained by the Brønsted-Lowry definitions of acids and bases, which defines acids as proton donors, and bases as proton acceptors. The Arrhenius definition of acids and bases requires a solvent to create a solution in which acids can donate hydrogen ions, and bases hydroxide ions. The white smoke reaction does not involve an ionising solvent, so cannot be explained by the Arrhenius definition of acids and bases.

Question 31 (8 marks)

The properties of three organic compounds, Q, R and S, are given in the table.

Compound	*Q*	*R*	*S*
Formula	CH_3CH_2COOH	$CH_3CH_2CH_2CH_2NH_2$	$CH_3CH_2CONH_2$
Molecular weight	74.08	73.14	73.09
Boiling point (°C)	141.2	78	213
pKa	4.88	10.21	

(a) Name the three compounds tabulated above. **3**

Criteria	Marks
• Provides 3 correct names	3
• Provides 2 correct names	2
• Provides 1 correct name	1

Q: propanoic acid

R: butan-1-amine

S: propanamide

(b) Write TWO equations to compare the reactions that occur when compounds Q and R are individually added to water. **2**

Criteria	Marks
• Writes two correct equations	2
• Provides one correct equation	1

Sample answer:

Propanoic acid donates a proton to water

$CH_3CH_2COOH(aq) + H_2O(l) \leftrightharpoons CH_3CH_2COO^-(aq) + H_3O^+(aq)$

Butan-1-amine receives a proton from water

$CH_3CH_2CH_2CH_2NH_2\ (l) + H_2O(l) \rightleftharpoons CH_3CH_2CH_2CH_2NH_3^+(aq) + OH^-(aq)$

(c) Provide reasons for the variation in boiling points between the three compounds described above, given that all have very similar molecular weights. **3**

Criteria	Marks
• Explains the intermolecular forces present in all three substances (i.e. hydrogen bonding) • Explains the high boiling points of carboxylic acid and amide compared to amine • Compares carboxylic acid and amide boiling points	3
• Addresses TWO of the above criteria	2
• Addresses ONE of the above criteria	1

Sample answer:

The boiling point of the carboxylic acid (acetic acid) is higher than that of the amine (butan-1-amine) due to the highly polar -COOH functional group, which is more polar than the -NH2 group. Although both functional groups can form hydrogen bonds, the O-H bond in the carboxylic acid is more polar than the N-H bond in the amine because oxygen is more electronegative than nitrogen. Due to the presence of the carboxyl group, carboxylic acids can also form dimers, resulting in very high boiling points.

The amide has a higher boiling point than both the amine and carboxylic acid. Like the carboxylic acid, it can hydrogen bond and form dimers, accounting for the very high boiling point. The higher boiling point than carboxylic acid is due to having two N-H bonds that can participate in hydrogen bonding, compared to the single O-H in the carboxylic acid.

Question 32 (4 marks)

Four 0.1M solutions of silver nitrate, lead nitrate, iron (III) nitrate and potassium nitrate are contained in separate, unlabelled bottles. Describe a series of laboratory tests that would successfully identify these solutions. Where appropriate, provide supporting chemical equations and predicted observations. **4**

Criteria	Marks
• Describes an appropriate series of tests to distinguish the four ions • Includes a relevant equation	4
• Describes an appropriate series of tests which could distinguish THREE of the ions • Includes a relevant equation	3
• Describes tests which can identify TWO of the ions	2
• Describes any test which can identify ONE of the ions	1

Question 33 (6 marks)

A conductivity titration was performed to determine the concentration of a hydrochloric acid solution. A 25.0 mL sample of the acid was placed into a conductivity cell.

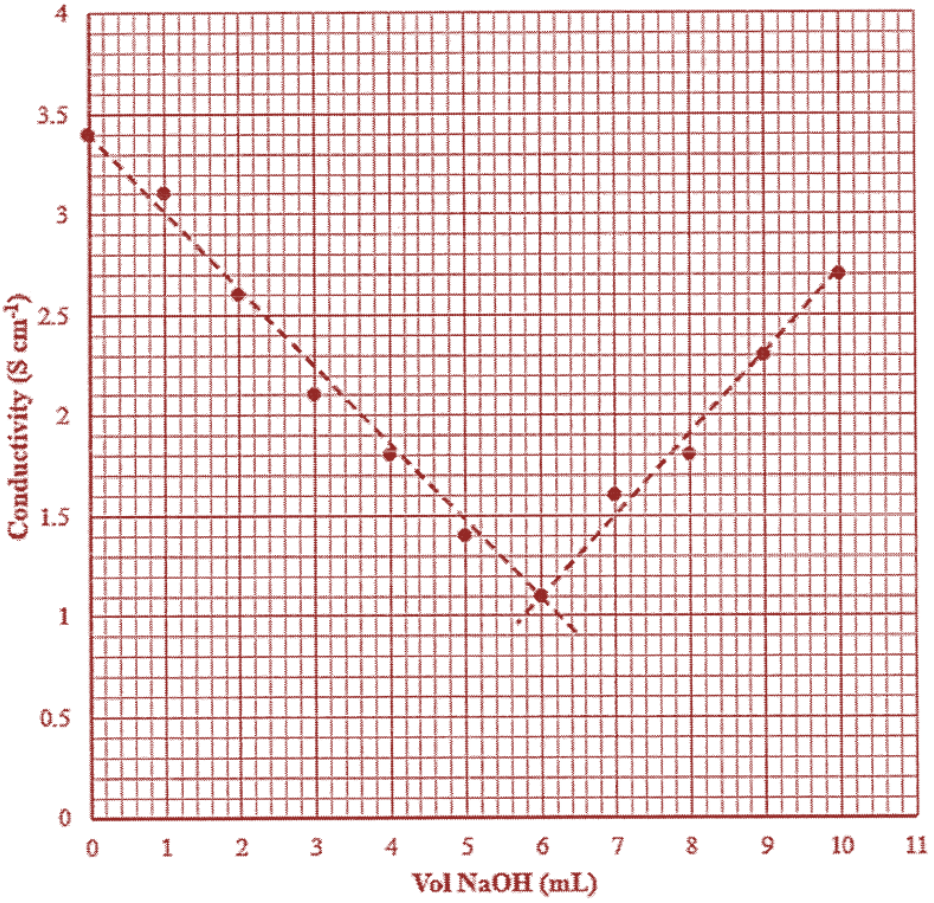
A burette was then used to slowly dispense volumes of 0.500 mol L^{-1} sodium hydroxide.

Conductivity readings were taken per 1 mL of sodium hydroxide added. Data was recorded in the following table.

Vol 0.5 mol L^{-1} NaOH (mL)	0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Conductivity (S cm^{-1})	3.4	3.1	2.6	2.1	1.8	1.4	1.1	1.6	1.8	2.3	2.7

Graph the data in the table using intersecting lines of best fit and perform relevant calculations to determine the concentration of the hydrochloric acid solution. **6**

Criteria	Mark
• Provides TWO intersecting lines of best fit • Points are accurately plotted • Scales are appropriate • Scales are correctly labelled with names and units • Correctly calculates the concentration of hydrochloric acid with units	6
• Provides a substantially correct graph • Correctly calculates a concentration of hydrochloric acid using appropriate steps	4–5
• Provides a mostly correct graph • Calculates a concentration of hydrochloric acid using an appropriate step	3
• Provides a mostly correct graph OR • Correctly calculates a concentration of hydrochloric acid using appropriate steps	2
• Provides some relevant information	1



$HCl + NaOH \rightarrow NaCl + H_2O$

Equivalence point – 6.00 mL of 0.500 mol L^{-1} sodium hydroxide is added

n NaOH = c × V = 0.5 × 0.006 = 3.0×10^{-3}

∴ n HCl = 3.0×10^{-3}

∴ [HCl] = n/V = $3.0 \times 10^{-3}/0.025 = 0.120$ mol L^{-1}

Question 34 (4 marks)

Compare the structures, properties and uses of TWO named addition polymers.

4

Criteria	Marks
• Identifies TWO addition polymers • Compares in some detail the structure, properties and uses of the addition polymers	4
• Identifies TWO addition polymers • Compares the structure, properties and uses of the addition polymers	3
• Identifies at least ONE addition polymer • Compares any TWO of the structure, properties and uses of the addition polymers	2
• Provides some relevant information that compares two addition polymers	1

Sample answer:

Polyethylene (PE) is an addition polymer produced when many ethylene monomer units (CH_2=CH_2) join to form a long carbon chain. Polyvinyl chloride (PVC) is an addition polymer produced when many chloroethene monomer units (CH_2=$CHCl$) join to also form a long carbon chain.

The monomers used to produce these two polymers both contain a double bond which "opens up" to allow the monomer units to join to form long carbon chains. The difference is that, for PVC, the monomer has a chlorine atom replacing one of the hydrogen atoms in ethylene. This means that every second carbon atom in the PVC chain has a chlorine atom attached. In the PE chain only hydrogen atoms are attached.

As both polymers contain long chains of carbon atoms, they have many properties in common. Both polymers are non-conductors of electricity (hence their use for electrical insulation) and both produce water resistant materials (hence their use in producing water-tight containers). The presence of the larger chlorine atoms along the PVC polymer chain increases bonding strength.

This results in the PVC polymer being more rigid and less flexible than the PE polymer. Polyethylene is therefore used to produce more flexible items such as plastic bags, clingwrap, water bottles and non-conductive coatings on flexible electrical wires. PVC is used in the production of more rigid products such as stormwater pipes, buckets, bins, and protective electrical conduit.

Question 35 (5 marks)

A 40.0 mL solution of 2.00×10^{-3} mol L^{-1} sodium sulfate is added to 200 mL solution of 2.00×10^{-3} mol L^{-1} lead (II) nitrate. Perform calculations to determine whether a precipitate of lead (II) sulfate will form.

5

Criteria	Marks
• Provides a correct balanced equation • Correctly calculates moles of both reactants • Correctly calculates concentrations of $[SO_4^{2-}]$ and $[Pb^{2+}]$ • Correctly calculates the ion product (Q) • Correctly states whether a precipitate will form	5
• Addresses THREE to FOUR of the above criteria	3-4
• Addresses TWO of the above criteria	2
• Provides some relevant information	1

Sample Answer:

$Na_2SO_4\,(aq) + Pb(NO_3)_2\,(aq) \rightleftharpoons PbSO_4\,(s) + 2NaNO_3\,(aq)$

$n(Na_2SO_4) = cv$

$= 2 \times 10^{-3}\ mol.L^{-1} \times 0.04\ L$

$= 8 \times 10^{-5}\ mol$

$n(Pb(NO_3)_2) = 2 \times 10^{-3}\ mol.L^{-1} \times 0.2\ L$

$= 4 \times 10^{-4}\ mol$

Total volume $= 0.240\ L$

$$[SO_4^{2-}] = \frac{n}{v} = \frac{8 \times 10^{-5}\ mol}{0.240\ L}$$

$$= 3.33 \times 10^{-4}\ mol.L^{-1}$$

$$[Pb^{2+}] = \frac{4 \times 10^{-4}\ mol}{0.240\ L}$$

$$= 1.67 \times 10^{-3}\ mol.L^{-1}$$

$[Pb^{2+}][SO_4^{2-}] = 3.33 \times 10^{-4} \times 1.67 \times 10^{-3}$

$= 5.56 \times 10^{-7}$

K_{sp} (from data sheet) $= 2.53 \times 10^{-8}$

IP $>$ K_{sp} so a precipitate will form.

Section II extra writing space

If you use this space, clearly indicate which question you are answering.

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If you use this space, clearly indicate which question you are answering.